Report as of FY2011 for 2011PA154B: "Assessing the Influence of Nutrient Sources to Urban Streams Through the use of Triple Nitrate Isotopes"

Publications

Project 2011PA154B has resulted in no reported publications as of FY2011.

Report Follows

Pennsylvania Water Resources Research Center
FY2011 Final Report

PROJECT TITLE AND PRINCIPAL INVESTIGATORS

Assessing the influence of nutrient sources to urban streams through the use of triple nitrate isotopes

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STATEMENT OF REGIONAL OR STATE WATER PROBLEM:

Like many "Rust Belt" cities, Pittsburgh's industrial history has left it with a legacy of pollution and an underfunded, aging infrastructure. Thirteen percent of Pennsylvania stream miles are impaired enough to significantly alter stream ecology (NRC 2005). Western Pennsylvania's water quality problems are often associated with acid mine drainage, the result of Pennsylvania's coal mining legacy. However, a report by the National Research Council stated that "the most pressing water quality problem [in Southwest Pennsylvania's urban core] is degradation of the microbiological quality of streams due to Combined Sewer Overflows (CSOs), Sanitary Sewer Overflows (SSOs) and discharge from separate stormwater systems in wet weather conditions" (NRC 2005). In Pittsburgh, this situation has led to a Federal Consent Decree in which the U.S. EPA and Pennsylvania Department of Environmental Protection require the Allegheny County Sanitation Authority to remediate sewage inputs to streams and rivers and "restore" one or more affected urban waterways in the city. The situation in Pittsburgh is representative of many urban communities, as combined sewer systems serve approximately 772 communities inhabited by about 40 million people in the US (USEPA 2009).

In addition to sewage inputs, urban areas are often dominated by impervious surfaces and storm sewer systems that accumulate and directly route pollutants, including atmospherically deposited nitrogen (AD) to streams, circumventing regions where nutrient processing occurs naturally (Driscoll, Whitall et al. 2003; Hatt, Fletcher et al. 2004; Wollheim, Pellerin et al. 2005). In regions with storm sewers, wet and dry AD washes into receiving waters from the land surface during rain (Wollheim, Pellerin et al. 2005; Burns, Boyer et al. 2008). The role of AD as a nutrient source is of particular concern in Southwestern Pennsylvania, which receives some of the highest rates of nitrate deposition nationwide (17- 21 kg/ha/yr). In order to both examine nitrate contamination sources and assess the influence each has on urban nutrient pollution, we will determine the isotopic composition of nitrate in water samples from NMR.
In addition to contributions to the scientific literature, we expect this work to contribute toward the fulfillment of goals indentified in the Watershed Monitoring and Advocacy plan, a strategic plan put forth by the Nine Mile Run Watershed Association (NMRWA), a volunteer group that "ensures[s] the restoration and protection of the Nine Mile Run Watershed through citizen engagement, demonstration projects, and advocacy." The strategic plan specifically requires that an appropriate program be created and implemented to monitor environmental conditions and impacts of programs using accepted environmental standards and sampling protocols. This proposed project will fulfill this goal of the NMRWA and moreover provide the NMRWA with data to benchmark progress and record environmental conditions, both to delineate the successes of current restoration efforts and guide future work. This project will document sources of

water quality impairment, including sewage overflows, provide the information required to make informed advocacy decisions, and create a foundation of data that will help establish the NMRWA as an effective advocate/partner in watershed transformation at the regional level.

Further, the recent consent decree, issued by the US EPA, requires the Allegheny County Sanitation Authority to "undertake measures necessary to comply with the Clean Water Act, including the Clean Streams Law" which mandates restoration of Pittsburgh waterways. This research will help inform the restoration process by distinguishing spatial and temporal variations in pollution inputs and determining the viability of "stream restoration" as a water quality management strategy. Finally, this research will serve as a template for monitoring water quality in other restored urban streams throughout the US.

NATURE, SCOPE, and OBJECTIVES:

Excess nitrate contributes to the overall degraded quality of streams in densely populated, human-engineered regions, compounding existing problems of pollution in urban landscapes. Urban centers, such as Pittsburgh, potentially contribute significant amount of nutrient pollution to large river systems, via concentrated emissions from industry, vehicles, and electric generating utilities, as well as from human-produced sewage. However, the relative contributions from multiple nitrate sources form a complicated mixture that is difficult to unravel with simple concentration chemistry. **The goal of this research is to quantify the relative proportions of atmospherically and sewage sourced nitrate contributing to urban surface water impairment through analysis of triple nitrate isotopes** ($\delta^{15}N$, $\delta^{18}O$, and mass-independent $\Delta^{17}O$ of nitrate).

In order to complete this study, water samples from Nine Mile Run, an urban stream in Pittsburgh, PA, were analyzed for nitrate concentrations and triple nitrate isotopes. To date, isotopic analysis of $\delta^{15}N$ & $\delta^{18}O$ has been completed on two years of bi-weekly stream samples (n=200) and two intensively-sampled storms (July 2008 & July 2010 n=32). Additionally, isotopic analysis of $\Delta^{17}O$ has been completed on a subset of bi-weekly baseflow samples (n=28) and both summer storms. Further analysis of the remainder of the baseflow samples and two winter storm samples is ongoing.

PRINCIPAL FINDINGS AND SIGNIFICANCE

These results indicate that the primary source of baseflow pollution is nutrient contamination from sewage resulting from cross-connections between the stream and leaking sewers. In order to quantify potential contributions of sewage to NMR, we used an inverse modeling approach to approximate N inputs and watershed N retention. The results of this analysis indicate that sewage-sourced nitrate contributes from 3 to 14 kg $ha^{-1}yr^{-1}$ to NMR inputs, equivalent to nearly 50% of the total nitrate load to the watershed (Divers et al., in revision for *Environmental Science & Technology*). Initial analysis of $\Delta^{17}O$ anomalies in bi-weekly samples suggests that AD is present in trace amounts during baseflow (generally less than 5%).

In comparison, during stormflows, nitrate originates from a mixture of sewers and atmospheric deposition wherein dry-deposited AD is washed from impervious surfaces. Initial isotopic analysis of $\Delta^{17}O$ and $\delta^{15}N$ from two storms sampled (July 20, 2008 and July 8, 2010) in NMR indicate that during high storm discharge events, AD can contribute up to 42% of the total nitrogen load to the stream. Ongoing $\Delta^{17}O$ analysis will help determine AD and sewage inputs influence streamwater nitrate concentrations on longer timescales (i.e. seasonally).

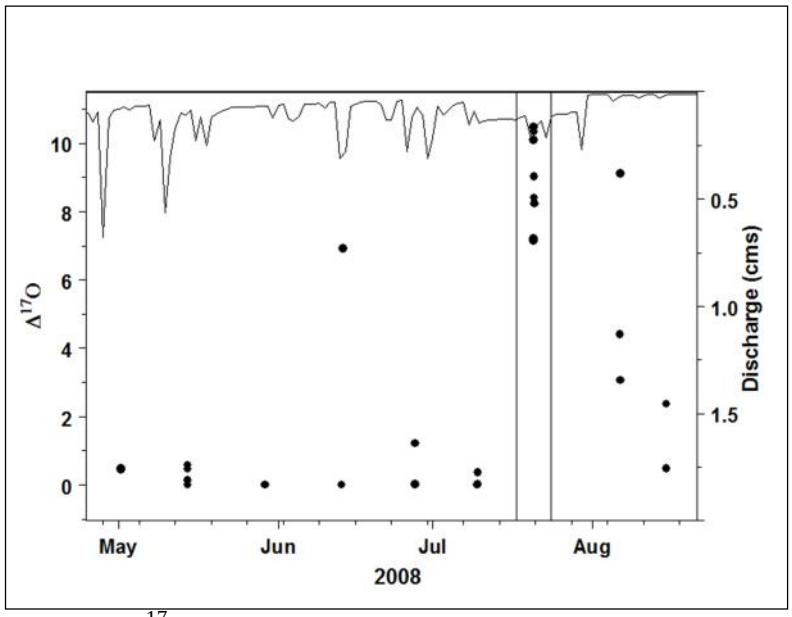

Figure 1 $\Delta^{17}O$ values for baseflow and July 20, 2008 storm (in rectangle). Also shown is stream discharge, for reference.

The results of this research will directly impact our understanding of the sources, effects, and remediation of nutrient pollution in Pennsylvania's urban streams. The primary product resulting from this project will be data that documents water quality and ecosystem health in NMR and establishes a baseline against which future changes in water quality can be measured. Furthermore, the data and interpretations will be provided to Pittsburgh and Allegheny County residents, NMRWA, the Pittsburgh Parks Conservancy, and scientists and policy makers via the NMRWA website (www.ninemilerun.org) in order that they may use the data for future urban revitalization projects and understanding Frick Park, an important regional asset.

STUDENTS & POSTDOCS SUPPORTED

Marion Divers, Ph.D. Candidate,
Kathleen Tuite, B.S., December 2011
Mollie Kish, B.S. Candidate

PUBLICATIONS

Divers, M.T., E.M. Elliott, and D.J. Bain, Constraining nitrogen inputs to urban streams from leaking sewer infrastructure using inverse modeling: Implications for DIN retention in urban environments. In revision for *Environmental Science & Technology*.

Tuite, Kathleen. 2011. "Determination of atmospheric nitrogen deposition within an urban watershed using ion exchange resins". Pennsylvania Water Resources Research Center, University of Pittsburgh, PA, 36pp.

PRESENTATIONS

- Elliott, EM. 2011. From the landscape to the continent: Gaining insight into the sources and fate of atmospheric reactive nitrogen emissions using stable isotopes. Abstract B411-03. Fall Meeting, American Geophysical Union, San Francisco, CA, 5-9 December, 2011.
- Sikora, MT, Elliott, EM, Bain, DJ. 2011. Constraining nitrogen inputs to urban streams from leaking sewer infrastructure using inverse modeling: Implications for urban water quality. Abstract H51P-06. Fall Meeting, American Geophysical Union. San Francisco, Calif., 5-9 Dec. 2011.
- Elliott, EM. Investigating Atmospheric-Terrestrial-Hydrologic interactions of reactive nitrogen using stable isotope geochemistry. Department of Geography & Environmental Engineering, Johns Hopkins University. November 15, 2011. Invited.
- Elliott. EM. Investigating atmospheric-terrestrial-hydrologic interactions of reactive nitrogen using stable isotope geochemistry. School of the Environment and Natural Resources. Ohio State University, Columbus, OH. May 12, 2011. Invited
- Elliott, EM. New frontiers in reactive nitrogen isotope geochemistry: Implications for water & air quality, ecosystem & human health. Department of Geology & Geography, West Virginia University, Morgantown, WV. April 1, 2011. Invited
- Elliott, EM. Reactive nitrogen emissions, deposition, and impact on water quality and human health. Department of Civil and Environmental Engineering, University of Pittsburgh, April 8, 2011. Invited

PHOTOS OF PROJECT

Figure 2: Eutrophication from nutrient excess in Nine Mile Run, Pittsburgh PA

Figure 3: Stormwater outfalls and mainstem of Nine Mile Run, Pittsburgh, PA